TULAREMIA AND DEER FLIES IN THE ENVIRONS OF UTAH LAKE, UTAH[1]

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Introduction

Deer flies have been implicated as mechanical vectors of tularemia in Utah. Although infected flies heretofore have not been found in nature, there is little doubt of their importance in transmitting tularemia to man. Two species present in this area, *Chrysops discalis* Williston and *Chrysops noctifer* Osten Sacken, have been shown experimentally to transmit the disease. The presence of deer flies in the environs of Utah Lake where tularemia is endemic offers a potential health threat to man, and the expanding human population and development of recreational facilities adjacent to the lake increase this potential. Despite the fact that deer flies have been implicated with tularemia in Utah, little is known about their distribution or seasonal occurrence in the environs of Utah Lake.

The objectives of this study are: (1) to determine the distribution and seasonal occurrence of deer flies in the environs of Utah Lake; and (2) to determine the incidence of tularemia pathogens in the deer flies.

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Review of Literature

Tularemia was first described by McCoy (1911) as a "plague-like disease" of rodents in Tulare County, California. McCoy and Chapin (1912) isolated the causative agent of the disease and named it *Bacterium tularense*. The taxonomic position of the pathogen is questionable. It is regarded by some as closely related to the pleuropneumonia group of organisms, and by others as more closely related to the genus *Brucella* than to its present position in the genus *Pasteurella* (Burrows, Porter, and Moulder, 1959). The name *Pasteurella tularensis* (McCoy and Chapin), as listed in Bergey's Manu-

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al of Determinative Bacteriology, 7th ed. (Breed, Murray, and Smith, 1957), will be used in this paper.

The taxonomy, description, and characteristics of *Pasteurella tularensis* are found in publications of Breed, *et al.* (1957), and Burrows, *et al.* (1959). Hesselbrock and Foshay (1945) described the morphology of the organism. Diagnostic procedures were described by Burrows, *et al.* (1959), Davidsohn and Wells (1963), and Frankel, Reitman, and Sonnenwirth (1963). Lillie and Francis (1936) described the gross pathology of tularemia in laboratory animals. The virulence of tularemia isolates from nature has been measured in laboratory animals by Green (1931), Davis, Philip, and Parker (1934), and Philip and Davis (1935). Definitive virulence tests have been developed by Francis and Feltan (1942), Bell, Owen, and Larson (1955), and Owen, *et al.* (1955). Jellison, *et al.* (1961) separated North American isolates of *P. tularensis* from nature into two major groups on the basis of virulence, reservoir host, seasonal distribution, and geographical occurrence: (1) tick-borne tularemia of rabbits, and (2) water-borne tularemia of rodents. Both groups are known to occur in Utah (Woodbury, 1955; Jellison, Kohls, and Philip, 1951).

Tularemia in Utah was first recognized by Pearse (1911). Francis (1919, 1921, 1929, 1937) listed numerous cases of human infection, but it was not until 1937 that the disease was sufficiently recognized by Utah physicians to accurately report its occurrence to state health authorities (Woodbury, 1955). The Utah State Department of Health reported 839 human cases of tularemia from 1937 to 1964, of which 26 were fatal (Thompson and Wright, 1964; Wright, 1965). During this period, 136 cases were attributed directly or indirectly to deer flies (Jenkins, 1965); 14 occurred in Utah County. The seasonal incidence of tularemia in Utah for a 17-year period coincides with the seasonal distribution of deer flies (Woodbury, 1955).

Tularemia in Utah was initially referred to as "deer-fly fever" when Pearse (1911) associated the deer fly *Chrysops discalis* with its transmission. Francis (1919, 1921), while investigating a disease of unknown etiology in Utah, recognized "deer-fly fever," isolated the pathogen, and named the disease tularemia. Although deer flies have not heretofore been found infected with tularemia in nature (Jellison, 1950), Francis and Mayne (1921) demonstrated that female *C. discalis* could be experimentally infected and were capable of transmitting the disease to laboratory animals. *Chrysops noctifer* has also been implicated experimentally as a mechanical vector of tularemia (Parker, 1933). Although only two species in the United States have been shown to be experimental vectors of the disease, Philip (1931) stated that other deer flies probably were capable of mechanical transfer of tularemia.

Jellison and Parker (1944) concluded that the primary reservoir of tularemia was rabbits, and Burroughs, *et al.* (1945) listed animals of 28 species as natural hosts of tularemia in the United States. Tularemia has been found in 33 mammal and 34 bird species in the Great Salt Lake Desert region of Utah (Bodé, 1963), but Marchette,

et al. (1961) concluded that tularemia in this region is primarily a disease of jack rabbits. Thirty-two of the mammal and 33 of the bird species listed by Bodé (1963) are known to occur in the Utah Lake area (Bee, 1947; Woodbury, Cottam, and Sugden, 1949; Durrant, 1962; Berrett, 1958; Hayward, 1965).

Correlation of the geographical distribution of human tularemia infections with the distribution of *Chrysops discalis* was shown by Jellison (1950). He concluded that although no infected deer flies had been found in nature and none had been found feeding on rabbits, circumstantial evidence indicated that *C. discalis* must be accepted as a vector of tularemia. Roth, Lindquist, and Mote (1952) subsequently observed deer flies biting the ears of wild rabbits.

Deer flies are placed taxonomically in the subfamily Pangoniinae of the family Tabanidae. The monograph of Brennan (1935) and catalog of Philip (1947) with its supplement (1950) summarize the present taxonomy of the Nearctic Pangoniinae and Tabanidae. The Pangoniinae of Utah were described by Rowe and Knowlton (1936). Lewis (1949) listed the taxonomy of the Tabanidae of Salt Lake County, Utah.

Distributional records of deer flies in Utah have been published by Knowlton and Thatcher (1934), Philip (1947, 1950), and Middlekauff (1950). *Chrysops fulvaster*, *C. aestuans*, and *C. discalis* were listed by Rowe and Knowlton (1936) as the common species of deer flies in salt-marsh areas of Utah.

The biology and ecology of deer flies in the western United States and Canada have been studied by Cameron (1926), Gjullin and Mote (1945), Roth and Lindquist (1948), Lewis (1949), and Roth, Lindquist, and Mote (1952).

Methods and Procedures

Eleven collecting sites in the environs of Utah Lake were chosen following an initial survey in April, 1964. Selection was made on the basis of plant association, larval habitat, and geographical location. Locations of the sites are shown in Figure 1, and a brief description of each follows:[3]

1. Orem Quadrangle, R. 2 E. x T. 6 S., Section 28, west center of section, elevation 4,500 feet. Station located 300 yards south-southwest of Orem City Sewage Disposal Plant and end of Powell Slough access road of the Utah Department of Fish and Game. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs and ponds.
2. Saratoga Springs Quadrangle, R. 1 W. x T. 5 S., Section 25, southeast corner of section, elevation 4,500 feet. Station located 50 yards south of Saratoga Springs resort swimming pools. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs and ponds.
3. Pelican Point Quadrangle, R. 1 E. x T .6 S., Section 32, west center of section, elevation 4,500 feet. Station located 0.9 mile south-southwest of Pelican Point pumping station. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs and drainage.

3. Topographical description of these sites was taken from United States Geological Survey Topographical Maps, 7.5 minute series, scale 1:24,000.

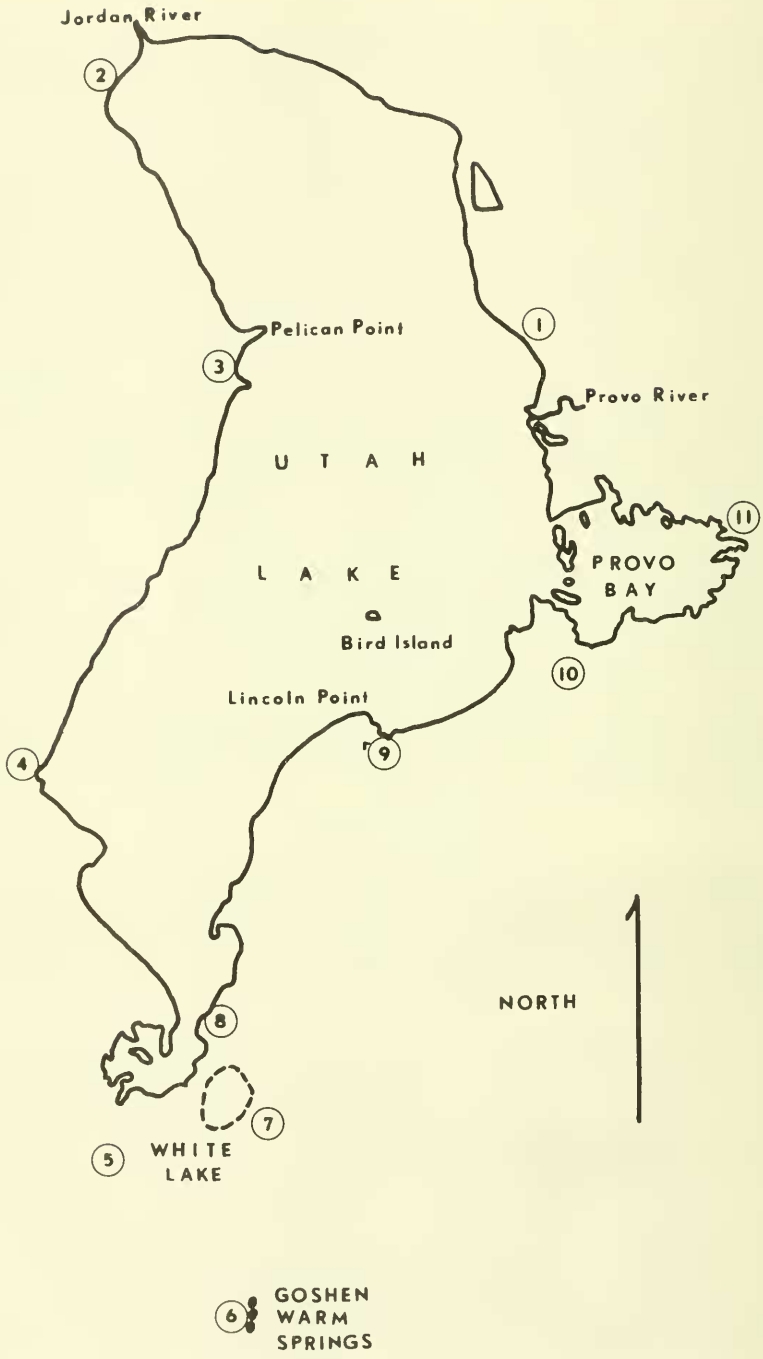

Fig. 1. Deer fly collection sites in the environs of Utah Lake, Utah.

4. Soldiers Pass Quadrangle, R. 1 W. x T. 8 S., Section 9, southeast corner of section, elevation 4,500 feet. Station located 1.1 miles southeast of Clyde Knoll. *Scirpus* spp. and *Distichlis* sp. present. Intermittant backwater of lake, no fresh-water springs.
5. Goshen Valley North Quadrangle, R. 1 W. x T. 9 S., Section 26, center of section, elevation 4,490 feet. Station located 3.5 miles north-northwest of Goshen school. *Scirpus* spp. and *Distichlis* sp. present. Intermittant fresh-water drainage stream.
6. Santaquin Quadrangle, R. 1 E. x T. 10 S., Section 8, west center of section, elevation 4,520 feet. Station located at Goshen Warm Springs. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs and ponds.
7. West Mountain Quadrangle, R. 1 E. x T. 9 S., Section 17, north center of section, elevation 4,500 feet. Station located 2.2 miles west of West Mountain peak, VABM 6904, and end of Lebaron Site access road of Utah Department of Fish and Game. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs and ponds.
8. West Mountain Quadrangle, R. 1 E. x T. 9 S., Section 20, east center of section, elevation 4,500 feet. Station located 2.1 miles west-northwest of Kiegley on east border of White Lake. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs, small ponds and drainage.
9. Lincoln Point Quadrangle, R. 1 E. x T. 8 S., Section 11, center of section, elevation 4,490 feet. Station located 0.7 mile south-southeast of Lincoln Point benchmark BM 4526, near mouth of Benjamin Slough. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water slough, springs, small ponds and drainage.
10. Provo Quadrangle, R. 2 E. x T. 8 S., Section 4, north center of section, elevation 4,500 feet. Station located 0.3 mile north of intersection of highway U 228 and Springville road. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs, drainage and standing roadside water.
11. Provo Quadrangle, R. 3 E. x T. 7 S., Section 17, west center of section, elevation 4,500 feet. Station located 100 yards west of General Offices, Pacific States Cast Iron Pipe Company. *Scirpus* spp. and *Distichlis* sp. present. Fresh-water springs, ponds, drainage and small stream.

Each site was visited for a one-hour period between 9 a.m. and 2 p.m. every two weeks from May through October. Collections were made on three consecutive days: Sites 1-4 were visited one day, Sites 5-8 the following day, and Sites 9-11 the succeeding day, alternating the hours of visitation of the areas collected on any given day. Adult female deer flies were attracted to me as I walked briskly through each area in a systematic pattern, stopping for several minutes every ten paces. As the attracted flies rose to attack or alighted on me, they were captured with an aerial insect net. Flies were frequently attracted to my automobile and were taken from its metal surfaces. Attempts at aerial capture of hovering flies or sweeping of vegetation proved futile. Captured flies were placed in an ethyl acetate killing jar.

After collections were completed at each site, the deer flies were removed from the killing jar and identified. The specimens were separated to species, thoroughly washed in sterile physiological saline solution, and put into four-dram screw-cap vials containing sterile, non-fat skim milk solution. Each vial was labelled externally with collection data, and frozen and stored at -30 C for subsequent bac-

teriological testing for the tularemia pathogen. Collection and other appropriate data were recorded for each site and collection. Temperature data were obtained from United States Department of Commerce Weather Bureau Climatological Data reports for Utah Lake, taken at Lehi, Utah.

Bacteriological investigations were conducted at the Epizoology Research Laboratory, Institute of Biological Environmental Research, University of Utah, Salt Lake City. Frozen deer flies were thawed and triturated in a mortar and pestal. Sterile, non-fat skim milk was added when required to insure sufficient innocula. Seventy-three pools were prepared, each containing not more than 15 flies of the same species, separated by area and date of collection. The supernatant from each pool was innoculated into one adult Hartley strain guinea pig and four adult Swiss-Webster strain white mice. Intraperitoneal injections of 1.0 cc per guinea pig and 0.5 cc per white mouse were given. Injected animals were caged and observed twice daily for a period of 28 days. Dead animals were removed on discovery, placed into separate containers, and stored at -30 C to await subsequent processing. Animals found dead within 24 hours after innoculation were discarded.

Aseptic necropsy procedures were used in the examination and processing of the dead animals. Each carcass was swabbed with 70 percent ethyl alcohol, the outer skin peeled back, and the thoracic and peritoneal cavities exposed. The gross pathology of the spleen and liver was noted, particularly for the swelling and mottling characteristic of tularemia infections. Sections of the spleen and liver were removed and plated on culture medium. After plating, the tissues were put into sterile vials and frozen for subsequent use. The culture medium used in testing for the tularemia pathogen was blood cystine heart agar (BCHA). It was prepared by dissolving 51 g of Difco Cystine Heart Agar (B47) in 950 ml of distilled water by heating in an 80 C water bath, adjusting to pH 7, autoclaving, and adding 50 cc of outdated, citrated human blood after cooling to 50 C in a water bath.

The plated BCHA media were incubated for 48 hours at 37 C and examined for characteristic colony growth. Typical colonies were subjected to Gram stain for determination of morphology and stain reaction. Slide agglutination tests were made on cultures demonstrating characteristic colony growth, morphology, and stain reaction. A slide agglutination titer of 1:80 or higher with complete agglutination was considered positive. Plates with positive slide agglutination test results, typical growth colonies, characteristic morphology, and Gram negative reaction were considered positive for *Pasteurella tularensis*.

Immediately after identification of the pathogen, the original tissue samples composing the positive isolation were examined and the pathogen reisolated from the infected tissues, confirming the initial isolation. Determination of the LD_{50} was made by testing various dilutions of the positive isolates in mice, rats, guinea pigs, and rabbits. Maximum virulence was established as an LD_{50} of nine

organisms or less for the test animals used. Test animals surviving the 28-day observation period were bled and the sera collected. The sera were subjected to a standard tube agglutination test for tularemia, using a known positive of 1:640 titer as a control. Final identification of *Pasteurella tularensis* was made on the basis of typical colony characteristics, morphology, animal pathogenicity, pathology, and slide agglutination test reactions.

Results

A total of 823 deer flies representing three spices was collected during this study (Table 1). Of the total number taken, 97.8 percent were *Chrysops fulvaster* van der Wulp, 1.92 percent were *C. aestuans* Osten Sacken, and 0.24 percent were *C. discalis* Williston. *Chrysops fulvaster* was collected from ten, *C. aestuans* from seven, and *C. discalis* from two sites. The greatest population occurred during the

Table 1. Distribution of deer flies by species, site, and collection period.

		Collection Period								
Site	Species[1]	June 14-June 27	June 28-July 11	July 12-July 25	July 26-Aug. 8	Aug. 9-Aug. 22	Aug. 23-Sept. 5	Sept. 6-Sept. 19	Sept. 20-Oct. 3	Site Total
1	Cf	1	8	60	2					71
2	Cf	2	6	28	56	2				94
	Ca			1	3					4
3	Cf		1	6	30	1				38
	Ca				1					1
4		None observed								
5	Cf				4					4
6	Cf	1	4	27	21	1	3			57
	Ca			1	1					2
7	Cf	2	4	43	114	102	17	11	1	294
	Cd				1					1
8	Cf	3	29	15	35	15	1	1		99
9	Cf	2	5	11	1					19
	Ca				1					1
10	Cf	3	9	14	5					31
	Ca			5	1					6
	Cd				1					1
11	Cf	1	7	68	22					98
	Ca		2							2
Totals	Cf	15	73	272	290	121	21	12	1	805
	Ca		2	7	7					16
	Cd				2					2

[1]Cf = *Chrysops fulvaster*, Ca = *Chrysops aestuans*, Cd = *Chrysops discalis*.

July 26-August 8 period. Female deer flies first appeared during the June 14-June 27 period, approximately one month after the last freezing temperature in May. Greatest populations coincided with weekly average maximum temperatures of 75 F or higher (Fig. 2). Deer flies were not observed after the September 20-October 3 period when temperatures of 32 F or below occurred. Positive thermotaxic response was noted for *C. fulvaster*.

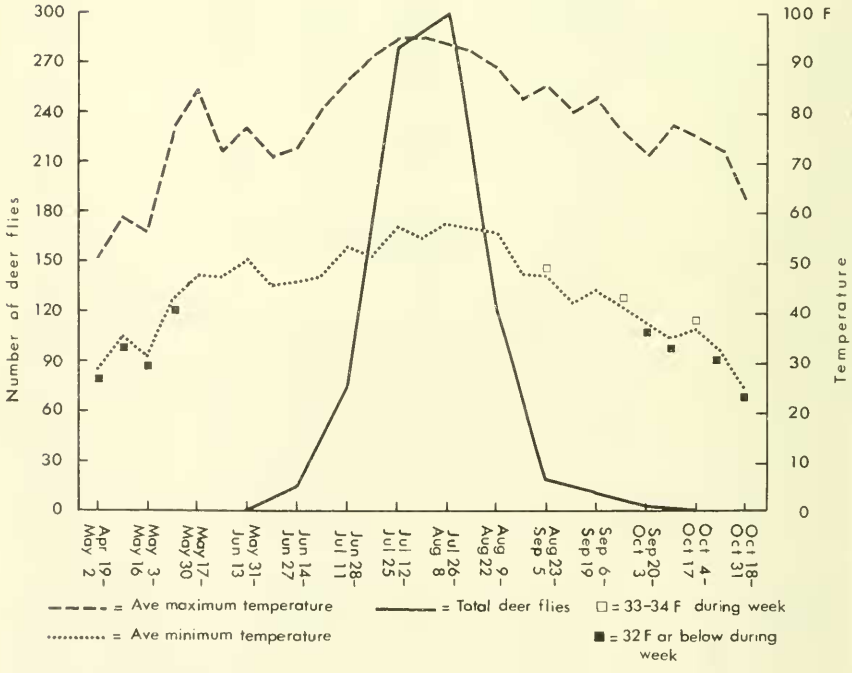

Fig. 2. Total numbers of deer flies captured each two-week period and weekly average maximum and minimum temperatures.

Sera tube agglutination tests of laboratory animals surviving the 28-day observation period were negative. Gross pathology was inconsistent. *Pasteurella tularensis* of maximum virulence was isolated from three of 73 pools tested. Isolations were made from one pool of five *Chrysops fulvaster* collected at Site 9, Lincoln Beach, on July 3, one pool of three *C. aestuans* collected at Site 2, Saratoga Springs, on July 27, and one pool of four *C. fulvaster* collected at Site 5, Goshen, on July 29 (Table 2). Slide agglutination tests of isolated and reisolated pathogen organisms demonstrated a titer of 1:80 or higher. Virulence tests of the isolates resulted in an LD_{50} of 10^0 (1 to 9 organisms).

Table 2. Isolation of *Pasteurella tularensis* from deer flies.

Pool no.	Deer fly species	Date collected	Site no.	No. flies in pool	Death day[1]	Virulence LD_{50}
2D2	*Chrysops aestuans*	July 27	2	3	6	10^{0}[2]
5D	*Chrysops fulvaster*	July 29	5	4	5	10^0
9B	*Chrysops fulvaster*	July 3	9	5	4	10^0

[1]Day of death of laboratory animal following injection for initial isolation.
[2]Nine or less organisms causing death.

Discussion

Occurrence and Distribution of Deer Flies

The three species of deer flies collected during this study, *Chrysops aestuans*, *C. discalis*, and *C. fulvaster*, were previously noted in the Utah Lake area by Knowlton and Thatcher (1934), and were listed by Rowe and Knowlton (1936) as those most common to salt-marsh areas in Utah. Other species have been listed for Utah from widely separated geographical areas and varied habitats, but the extent of their distribution in the state is largely unknown (Knowlton and Thatcher, 1934; Rowe and Knowlton, 1936; Philip, 1947, 1950; Middlekauff, 1950). One record of *Chrysops lupus* Whitney was listed for Provo by Knowlton and Thatcher (1934), but no subsequent collections of this species have been reported in this area.

The period of activity of the deer flies in this study corresponds with the observations of Gjullin and Mote (1945) at Summer Lake, Oregon, who noted that deer flies were active from the middle of June to the first part of September. Roth and Lindquist (1948) noted that the peak abundance of flies for a two-year period occurred during the last part of July and the first part of August. Cameron (1926) noted activity of *C. aestuans* from the first part of June into July.

The seasonal occurrence of the flies collected during this study showed variation with different species. The flies first observed were

C. fulvaster on June 24. These were subsequently taken at various sites until September 26, the peak abundance occurring during the July 26-August 8 period. The limited number of *C. aestuans* collected precludes conclusions as to their seasonal occurrence and distribution, but their activity during June and July corresponds with the observations of Cameron (1926). Comparative numbers of *C. aestuans* and *C. fulvaster* collected in this study support the contention of Rowe and Knowlton (1936) that *C. aestuans* is often taken with *C. fulvaster* but is less abundant. Insufficient collections of *C. discalis* preclude any conclusion on its activity other than that it was present in the study area. Its absence in habitats with which it is usually associated suggests that some factor or combination of factors resulted in the minimal number noted in this study.

The most abundant species, *C. fulvaster*, was collected at all sites at which activity was noted (Table 1), which suggests that the conditions at these sites were favorable for this species. *Chrysops aestuans* was taken at six sites. Its presence at some sites and absence from others of almost identical habitat is unexplained other than that the species is not abundant in the study area, as noted by Rowe and Knowlton (1936). *Chrysops discalis* was captured at two sites. No explanation is offered as to the scarcity of this species in typical habitat sites in the study area other than that extrinsic factors may have reduced its numbers.

The daily activity of deer flies between 9 a.m. and 2 p.m. corresponds with that noted by Roth and Linquist (1948) and Roth *et al.* (1952). The period of activity may be attributed to warming of cool morning air to an optimum temperature. Few flies were active between 2 p.m. and 5 p.m., but a slight increase was noted at dusk. Little activity was observed during periods of strong wind, regardless of time of day.

The positive thermotaxic response to the metal surfaces of my automobile when stationary in open sunlight, particularly during early morning hours, as noted for *Chrysops fulvaster*, is similar to that observed for *C. aestuans* by Cameron (1926) and for *C. discalis* by Lewis (1949).

Factors Affecting Deer Fly Populations

Deer flies are associated by oviposition with particular plants. In studies at Summer Lake, Oregon, oviposition was noted on the sedges *Scirpus americanus* and *S. paludosus* (Gjullin and Mote, 1945; Roth and Lindquist, 1948). Lewis (1949) described oviposition by *C. discalis* on the salt-marsh grass *Distichlis stricta* in Salt Lake County. Cameron (1926) observed oviposition by *C. aestuans* on *Scirpus* sp. and other emergent aquatic plants. The major criterion for the selection of collection sites in this study was the presence of *Scirpus* sp. and *Distichlis* sp., although such factors as water source and area, larval habitat, and geographical location also were considered. No flies were observed at Site 4 even though it possessed the plant species usually associated with deer flies. Although Roth

and Lindquist (1948) encountered flies up to two miles from breeding areas, the absence of flies from an area with typical associated plant species suggests that other factors may be essential for deer fly populations. All collecting sites except Site 4 were characterized by fresh-water springs, ponds, or drainage. The water at Site 4 was brackish, intermittent backwater of Utah Lake, with a sand and gravel bottom. The water sources at all other sites varied in size, but all drained alkaline soil, and the bottom of the water area was covered with thick, black muck, rich in organic debris typical of lentic habitats. The abundance of deer flies in these areas substantiates findings in their life history by Philip (1931) and Roth and Lindquist (1948) who discovered larvae and pupae in similar habitats. Philip (1931) described larval habitats of deer flies and associated *C. aestuans* with lentic conditions, and *C. fulvaster* with both lotic and lentic conditions. Lewis (1949) found *C. discalis* in brackish, alkaline ponds in lentic associations. The life cycle and abundance of deer flies appears to be dependent upon proper larval and pupal habitats as well as particular plant species for oviposition. The absence of flies at one site where appropriate plant species were present but where proper water habitat and larval and pupal environments were missing, supports this allegation.

The size of the breeding area may influence deer fly populations. Except for Site 4, all sites had alkaline drainage and bodies of water of various sizes. Sites 1, 6, 7, and 8 had very large water areas, and a comparison of the number and extent of deer fly collections at these sites (Table 1) reveals that all except Site 1 were characterized by large numbers of flies, an activity period of long duration, and a near normal curve of fly activity during the study period. Sites 3, 9, 10, and 11 had relatively small water areas, and were characterized by increasing numbers of flies until the July 26-August 8 period when the activity decreased abruptly, and then ceased entirely by the August 9-August 22 period. At Site 5, where a small intermittent stream drained an alkaline meadow, there was no activity during the study except for the July 26-August 8 period when large amounts of water were present and overflowed the stream into the adjacent meadow. The flies captured at this site may have been transients from nearby areas. Comparison of the number and activity of deer flies with the size of the water area and type of drainage indicates a correlation between the two factors.

Comparison of the number of deer flies collected each two-week period and the average weekly maximum and minimum temperatures (Fig. 2) suggests a relationship between temperature and deer fly activity. The weekly average maximum temperature rose to approximately 70° F before initial deer fly activity was observed, and maximum activity was noted when the weekly average maximum temperatures were 75° F or higher. This agrees with the findings of Roth *et al.* (1952) who observed greater activity of *C. discalis* when the temperature was above 75° F, and Davies (1959) who noted that peak abundance of *Chrysops* spp. occurred when the maximum temperature rose to 80° F, especially when this temperature was

several degrees higher than the maximum of the preceding few days. The activity of the flies dropped sharply when the first near-freezing temperatures occurred during the week of August 23-29, and activity ceased with freezing temperatures during the last weeks of September. Freezing temperatures in the weeks of April 19 to May 9 may account for the minimal collections of *C. discalis* in this study. According to the observations of Lewis (1949), this species is normally active from April to September. If adult flies had emerged and were active as described, the freezing temperatures of April and May would have killed most of the emergent flies, and only those surviving or emerging after the freezing temperatures would have been present during this study. *Chrysops fulvaster* and *C. aestuans* apparently were not affected by the freezing spring temperatures, suggesting that these species emerge later than *C. discalis*. The sharp decline in activity at some sites when temperatures near 100° F occurred during the last three days of July agrees with the findings of Jamnback and Wall (1959) who observed that extended periods of high temperatures resulted in a sharp decrease in deer fly activity. The gradual decrease in activity at Sites 6, 7, and 8 may have resulted from an insulating effect of the large water areas at these sites and offered some protection from the effects of high temperature.

Deer fly activity at Site 1, where extensive water area, alkaline drainage, and associated plant species were present, declined abruptly after aerial spraying for mosquito control on July 27. A total of 68 *Chrysops fulvaster* had been collected at Powell Slough during the previous collecting period, but on the day of spraying only two specimens were taken, and none thereafter. The Utah County Health Department entomologist (Davis, 1965) revealed that the spray used was Parathion, applied at one pound per acre in an oil emulsion, and that spraying also had been done in the areas of Sites 1, 2, 9, and 11 during May and the first week in June. The effect of the May and June insecticide applications on *C. fulvaster* and *C. aestuans* is unknown, since no activity was noted for these species until later in June and July, several weeks after spraying. If the seasonal dynamics of *C. discalis* in the study area were similar to the activity noted by Lewis (1949), the May and June applications of insecticide may well account for the small numbers of this species collected during this study. The apparent complete absence of deer flies following the July 27 application of insecticide suggests that aerial spraying may effectively control adult female deer fly populations.

The species occurrence and geographical distribution of deer flies observed in this study may be related to several factors. Even though the 11 collecting sites in the environs of Utah Lake were selected on the basis of specific plant associations, larval habitat, and general environment similar to those noted by previous workers (Cameron, 1926; Gjullin and Mote, 1945; Roth and Lindquist, 1948; Lewis, 1949; Roth *et al.*, 1952), the sites may not have possessed habitats favorable to all species of deer flies. In order to insure as large a number of deer flies as possible for subsequent bacteriological

examination, sites with apparent atypical habitats were not selected. An attempt was made to collect from a variety of habitats and to encompass the periphery of the lake and its environs. When possible, sites were selected on the basis of their proximity to areas of human habitation, agriculture and recreation. Collections from additional sites were limited by time, methods, and transportation requirements.

Isolation of Tularemia Pathogens

The isolation of *Pasteurella tularensis* from three pools of flies containing *Chrysops fulvaster* and *C. aestuans* substantiates the conclusion of Philip (1931) that deer flies other than *C. discalis* and *C. noctifer*, which had been implicated as mechanical vectors in laboratory experiments (Francis and Mayne, 1921; Parker, 1933), may be involved as vectors of tularemia. Pathogens were found in flies during the time of greatest fly populations and seasonal period when the greatest numbers of human tularemia cases were recorded over a 17-year period in Utah (Woodbury, 1955). Pathogens were also found in deer flies taken during an earlier period when fly populations were small, but well within the seasonal period of highest incidence in humans as noted by Woodbury (1955). The correlation of deer fly populations observed during this study with the seasonal incidence of human infections strongly implies that deer flies are a major source of human infections in Utah. Utah State Department of Health statistics list 136 of 839 cases of human infections as being directly or indirectly associated with deer flies, but 703 reports did not state the source of infection (Jenkins, 1965). It is possible that many of the unstated cases could be attributed to deer flies.

The geographical distribution of the infected flies does not show a significant pattern, although the distribution suggests that an endemic tularemia focus may be located at the southern end of Utah Lake.

The presence of a highly virulent strain of the pathogen indicates that a natural reservoir exists among the native fauna. Whether such reservoir animals are resistant to the strain is not known. No evidence of an epizootic was observed during the study in any of the areas, although many of the animal species known to be infected with tularemia in Utah (Bodé, 1963) are known to occur in the Utah Lake area (Bee, 1947; Woodbury *et al.*, 1949; Durrant, 1952; Berrett, 1958; Hayward, 1965). Rodents and lagomorphs were occasionally observed in collecting areas, particularly near Site 2, where large numbers of squirrels were present at a garbage dump adjacent to a resort.

Although it is possible that only three of 823 deer flies were infected, the isolation of the pathogen from deer flies is medically significant. Previous implications of deer flies as mechanical vectors of tularemia have been based on the results of experimental evidence for two species, *C. discalis* and *C. noctifer* (Francis and Mayne, 1921; Parker, 1933), and to this time no infected flies have

been taken in nature (Francis and Mayne, 1921; Jellison, 1950). It has been assumed on the basis of circumstantial evidence (Jellison, 1950), that deer flies are responsible for the transmission of tularemia to humans. Tularemia has been found in rodents, lagomorphs, and other vertebrates (Burroughs *et al.*, 1945; Bodé, 1963); deer flies have been observed biting rabbits (Roth and Lindquist, 1948) and have been associated with human tularemia infections (Pearse, 1911; Francis, 1919, 1929; Jellison, 1950; Jenkins, 1965); and now to complete the chain of infection, *Pasteurella tularensis* has been found in deer flies in nature.

Recommendations for Further Study

The isolation of tularemia pathogens from deer flies in areas where human infection is probable is significant, and on this basis additional studies should be undertaken. Suggestions for further investigation arising from this study are:

(1) A comprehensive study should be made of a wide selection of habitats and geographical areas over several years to determine the occurrence, distribution, and seasonal dynamics of all the species of biting flies in the environs of Utah Lake.

(2) An extensive investigation of deer flies should be made to determine the time, place, and duration of infection by *Pasteurella tularensis.*

(3) An investigation of the pathogen isolates should be made to determine the strains present and their virulence.

(4) A comprehensive study of the potential reservoir animals in the environs of Utah Lake should be made to determine species, populations, distribution, and seasonal occurrence of the animals, and the incidence and virulence of tularemia in the native fauna.

(5) An investigation of the human population in the environs of Utah Lake should be made to determine the extent of clinical and subclinical infections.

Summary and Conclusions

On the basis of this study the following data are presented:

1. A total of 823 adult female deer flies representing three species was collected during the spring, summer, and autumn of 1964 from 11 collecting sites in the environs of Utah Lake, Utah. *Chrysops fulvaster* was the most abundant, *Chrysops æstuans* the next, and *Chrysops discalis* the least abundant.
2. Deer flies were found only in areas with fresh-water springs, ponds, or drainage.
3. Deer flies appeared approximately one month after the last freezing temperatures in May, and disappeared after the first freezing temperatures in September. Maximum activity of

the flies occurred between July 26 and August 8 when the weekly average maximum temperature was 75° F or higher.

4. The abundance of deer flies appeared to be dependent upon the size of breeding areas, typical larval habitats, and the presence of particular plant species.
5. Positive thermotaxic response was noted for *Chrysops fulvaster*.
6. The causative agent of tularemia, *Pasteurella tularensis*, was isolated from three of 73 pools of deer flies. Isolation was made from one pool of five *Chrysops fulvaster* collected at Lincoln Beach on July 3, one pool of three *C. aestuans* collected at Saratoga Springs on July 27, and one pool of four *C. fulvaster* collected at Goshen on July 29.
7. The presence of tularemia pathogens in deer flies near areas of human habitation, agriculture, and recreation in the environs of Utah Lake, Utah, represents a public health threat for which appropriate preventive measures should be taken.
8. Aerial spraying of appropriate insecticides may control adult female deer fly populations.

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